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ELBOW 2001 - Studying the Relationship between Lake Breezes and Severe Weather: Overview and Latest Results, David Sills, MSC King City ON, Peter Taylor, York University, Patrick King, MSC Toronto ON, Wayne Hocking, Univ. of Western Ontario, and Ian Nichols, Univ. of Guelph - Ridgetown College

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Development and Application of Operational Wind/Wave Relationship Guidance for Northern Michigan, Steve Rowley and Bruce Smith, NOAA/NWS Gaylord MI

Great Lakes Water Levels, Keith Kompoltowicz, U.S. Army Corps of Engineers, Detroit MI

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The Role of Mid-Level Jet Intensification in the 21 July 2002 Upper Michigan Convective High Wind Event, Kevin Crupi, NOAA/NWS Marquette MI

The 9 April 2001 Severe Weather Outbreak, Rodney Smith and Angela Lese, NOAA/NWS Syracuse IN

The May 21 2001 Tornado Outbreak, Randy Graham, NOAA/NWS Grand Rapids MI

The September 9 2001 Lansing F1 Tornado, Rob Dale, WLNS TV-6 Lansing MI

The 24 October 2001 Tornado Outbreak, Jeff Logsdon, John Taylor, Pat Murphy, Sam Lashley, Rodney Smith, and Kevin Barjenbruch, NOAA/NWS Syracuse IN

The August 1 2002 Northern Michigan Tornadoes, Bruce Smith, NOAA/NWS Gaylord MI

The August 1 2002 Series of Bow Echo Storms Across the Central Great Lakes as Seen by the New Canadian Radar Processing System, Michael Leduc, MSC Downsview ON

The Medium and Large Scale Environments Associated with Severe Rainstorms in Ontario, Brian Murphy, MCS Burlington ON

Heavy Rainfall – June 9-11, 2002 – The Northern Minnesota, Southeastern Manitoba, and Southern Northwestern Ontario Flooding Event, James Cummine, MSC Winnipeg Manitoba, Brian Murphy, MCS Burlington ON

Lake Effect Thunder-Snows Over the Eastern Great Lakes, Bob Hamilton, NOAA/NWS Buffalo NY

Simulation of Cloud Bands Associated with Lake Effect Snowstorms, G.W.K. Moore and Anthony Liu, Univ. of Toronto, K. Tsuboki, Nagoya Univ.

Assessing the Impact of Great Lakes Water Temperature Fields on Snowfall Production Using the Work Station Eta Model, Tom Niziol, NOAA/NWS Buffalo NY

Lake-effect Snowstorms Associated with Synoptic-scale Cyclones over Southern Ontario, Anthony Liu and G.W.K. Moore, Univ. of Toronto

Synoptic and Mesoscale Aspects of a Significant Lake Enhanced Snow Event over Northern Michigan, Jeff Zoltowski and Bruce Smith, NOAA/NWS Gaylord MI

The Effects of Topography on Snowfall in Upper Michigan, Thomas Hultquist, NOAA/NWS Marquette MI

The 1 March 2002 Upper Michigan Heavy Snow Event: Utility of a Local Mesoscale Model in the Forecast Process, James Sieveking, NOAA/NWS Marquette MI

An Analysis of an Unexpected 12 Inch Snowstorm Across Southern New York State, Michael Jurewicz and Michael Evans, NOAA/NWS Binghamton NY

A Compare and Contrast Study of Two Banded Heavy Snow Events, Michael Evans and Michael Jurewicz, NOAA/NWS Binghamton NY

Improving Snowfall Forecasting by Diagnosing Snow Density, Sara Bruening and Paul Roebber, Univ. of Wisconsin in Milwaukee

Waterspout Structure, Wind Speeds, and Forecasting, Joe Golden, NOAA/FSL Boulder CO

Waterspouts Over the Great Lakes, What We Can See, Wade Szilagyi, MSC Toronto ON

FSL Research and Projects Update, Joe Golden, NOAA/FSL Boulder CO

Policy and Preparedness for Local Damage Surveys and Other Investigations, Peter Chan, WXMI FOX 17 TV, Grand Rapids MI

The Increased Verification of Severe Thunderstorms (INVEST) Program: Training for Damage Surveys, Ernie Ostuno, NOAA/NWS Grand Rapids MI

Grand Rapids Winter Storms Climatology, Randy Graham, NOAA/NWS Grand Rapids MI

Classifying Lake Effect Snow Storms, Jim Kosarik, NOAA/NWS Cleveland OH

A Climatology of Northern Michigan Tornadoes, Daniel Valle and Brian Hirsch, NOAA/NWS Gaylord MI

Satellite and Lightning Climatology for the Great Lakes, Patrick King, MSC Toronto ON

The Influence of the Lake Erie Lake Breeze on Thunderstorm Initiation

Robert LaPlante
NOAA/NWS Cleveland OH

Dr. David Kristovich
University of Illinois
Illinois State Water Survey

The NWS Weather Forecast office in Cleveland OH (WFO CLE), the Illinois State Water Survey, and the University of Illinois are participating in a COMET collaborative project that seeks to better understand the influence of the Lake Erie lake breeze front on thunderstorm initiation and evolution.

Surface, sounding, satellite, and KCLE WSR-88D radar data for the warm seasons of 1999 and 2000 are examined to determine the locations of initial thunderstorm development and how these locations are related to the lake breeze front. The subsequent intensity of the thunderstorms, as determined through VIL analyses, is compared between storms forming near and far from the lake breeze front. Analyses of how environmental conditions influence the relative intensity of storms near the lake breeze front are determined through examination of surface and nearby sounding data. The project will also attempt to determine the influence of other boundary layer convergence zones on thunderstorm initiation near the lake breeze.

Climatological statistics on the Lake Erie lake breeze, rainfall frequency in the WFO CLE warning area, and the frequency with which thunderstorms developed near the lake breeze will be presented. Two case studies of convective development along the lake breeze will be compared. One case will show intense thunderstorm development near the lake breeze front while the other case will exhibit weaker convection near the front.

Using the Workstation Eta Model for Operational Forecasting of Heavy Rainfall from a Lake Breeze

Bill Wilson
NOAA/NWS Romeoville IL

The National Weather Service has made available a model that can be run on small workstations. This model is called the Workstation Eta. This paper describes a study in the utilizing the Workstation Eta model for operational forecasting of convective precipitation as a result of the lake breeze.

A comparison of the two cumulus parameter schemes, the Kain and Fritsch and the Betts Miller and Janjic was made using a heavy rain event in northeast Illinois. The low level convergence associated with the heavy rain band may have been related to the lake breeze. The results of the comparison will be used in further studies of convection and heavy rain events as a result of the lake breeze.

Numerical Investigation of Convective Modulation via Interaction with a Lake Breeze

Greg E. Mann
NOAA/NWS Detroit/Pontiac MI

Convection-boundary interactions have recently received appreciable attention from the research community. Much of the effort has been focused upon the interaction of supercell thunderstorms with pre-existing boundaries and its role in tornadogenesis. Furthermore, boundary induced convective initiation, especially with respect to sea (lake) breezes, has also been studied extensively. However, very little research, beyond observational studies, has focused on potential morphological changes to existing convection by pre-existing boundaries. This study is a preliminary numerical investigation of ordinary convective cell interactions with a pseudo-lake breeze boundary. Several sensitive simulations were performed using the Weather Research and Forecasting model (WRF) at 500m grid spacing to investigate the role of boundary interaction with the morphological evolution of a prescribed convective cell; specifically, the potential transition from an ordinary weakly organized single cell system to one with supercell characteristics and greater longevity. These systems tend to be much more apt to produce severe weather during their life cycles, especially large hail (>golf ball size) and severe winds. Preliminary results will be presented along with an overview of future work.

ELBOW 2001 - Studying the Relationship Between Lake Breezes and Severe Weather: Overview and Latest Results

David Sills[1], Peter Taylor[2], Patrick King[3], Wayne Hocking[4] and Ian Nichols[5]

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The Meteorological Service of Canada, York University, University of Western Ontario and University of Guelph - Ridgetown College conducted a field experiment from June to August of 2001 in southwestern Ontario as part of the Effects of Lake Breezes On Weather (ELBOW) project. The goal of ELBOW is to better understand the relationship between lake breezes and severe weather, including heavy rain, hail and tornadoes. The anticipated benefits of the study include concepts, tools and algorithms that will help forecasters use lake breeze data in real time to assess the severe weather threat and tailor watches and warnings accordingly. This will hopefully result in more accurate watches / warnings and longer lead times.

The stable marine air delivered by lake breezes generally suppresses convective activity over and immediately downwind of the Great Lakes. However, the lake breeze front can serve as a convective triggering mechanism. This is especially true when lake breeze fronts interact or when they collide with thunderstorm gust fronts. Southwestern Ontario, surrounded by lakes on three sides and home to much of Canada’s most severe weather, is an ideal location for this study.

Experimental instrumentation included the NRC Twin Otter research aircraft, a Cessna equipped with an Aventech instrument package, a 14 station mesonet, 4 rawinsonde systems, 2 wind profilers, a portable X-band Doppler radar and mobile observation equipment. These platforms were located within the effective Doppler range of the Environment Canada operational weather radar located in Exeter, Ontario, since this radar is well-suited for detecting low-level boundaries in optically-clear air. Much of the field instrumentation was operated only during intensive observation days, of which there were 29 over the study period. A special version of the MSC operational regional forecast model (GEM) with 2.5 km horizontal grid spacing was also run daily in support of the experiment.

Summer 2001 was hot and unusually dry in southwestern Ontario resulting in frequent lake breezes and less severe weather than usual. Preliminary work indicates that Lake Huron and/or Lake Erie lake breezes developed on over 70% of study days. Severe weather occurred during daylight hours on 6 study days and, in at least 5 of these events, it appears that severe thunderstorms were either initiated or enhanced at lake breeze fronts. A number of interesting events with interactions between lake breeze fronts and other low-level boundaries were also captured.

An Experiment in Subjective Probabilistic Quantitative Precipitation Forecasting: Forecasts and Verification during the ELBOW 2001 Field Study

Brian P. Murphy[1], Arnold Ashton[2], Patrick King[3], David M.L. Sills[4]

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The Effects of Lake Breezes On Weather (ELBOW) 2001 was a field study conducted by the Meteorological Research Branch (MRB) of the Meteorological Service of Canada in association with several Ontario Universities including York University. One of the goals of the project was to study lake breeze fronts to determine the role that such convergence lines play in generating severe weather. It also offered a unique opportunity to test the utility of the issuance of subjective Probabilistic Quantitative Precipitation Forecasts (PQPF) for several point locations within the field study domain over a large part of southwestern Ontario. The ELBOW 1997 field study (King and Sills, 1998) and other works identified that many excessive rainfall producing quasistationary Mesoscale Convective Systems (MCS) in southwestern Ontario are largely governed by the development and propagation effects of lake breeze boundaries. Previous research has also demonstrated the value and merit of PQPF as valuable guidance for flood forecasting and risk management in small to medium sized watersheds (Krzysztofowicz, 1998).

The experimental PQPF products for ELBOW 2001 are described as well as the preliminary verification results. Two brief case studies are also presented.

ELBOW 2001 Case Studies

Lisa Alexander
York University, Toronto Ontario

The Effects of Lake Breezes on Weather (ELBOW) 2001 project was started last summer in the hopes that data taken would help us to better understand the way that lake breezes interact with one another and incoming synoptic features. With a better understanding of these lake breezes we hope to improve forecasts in Southwestern Ontario. The data taken included aircraft, mesonet, radiosonde, mobile observations and measurements, X-band Radar, and a number of other archived data. In preliminary case studies we are able to see that days with similar initial conditions, such as background flow direction and strength, synoptic situations, and lake breeze development, do not always have the same outcome. In studying these cases we hope to better understand how storms develop or lack development in relation to lake breeze interaction with other boundaries.

Ultrasonic Snow Depth Sensors: Investigating Their Application to NWS Snowfall Measurements

Edward J. Shimon
NOAA/NWS Duluth MN

With the implementation of the Automated Surface Observing System (ASOS) in airports across the country in the mid-1990s, observations of snowfall and snow depth were no longer reported on a regular basis. The ASOS was developed by the National Weather Service (NWS) to replace the routine manual observation of weather elements with automated methods. ASOS uses advanced electronic and electro-optical (E-O) sensors and computer based algorithms to replicate the human decision making processes. Snow depth measurements were not initially available in ASOS. It is anticipated that results of local studies may be used to assess the feasibility of incorporating information about snow accumulation into the ASOS observation.

This study examined the suitability of two ultrasonic snow depth sensors as a potential solution to the scarcity of consistent and accurate snowfall measurements. The sensors used were the Judd Sensor and the Campbell Sensor. A key component of this study was to manually take co-located snowfall and snow depth measurements simultaneously with the automated sensor. Data analysis was then done, with emphasis on the reliability and accuracy of the information. Sensor comparisons were also conducted to determine the most accurate model.

A Simple and Inexpensive Method to Measure Snow Water Equivalent of a Snowpack

James LaRosa
NOAA/NWS Marquette MI

A review of the widespread flooding which occurred across Upper Michigan in April 2002 found that additional snow water equivalent data would have enhanced the accuracy of river forecasts. The majority of snow water equivalent data from Spring 2002 in Upper Michigan was supplied by WE Energies, was limited to the Menominee River basin (the focus of their hydroelectric operations), and was reported approximately once per month. Since significant flooding occurred in other areas, a cost effective method of measuring the water equivalent of a snowpack was needed.

It was determined that a length of stainless steel muffler pipe, the plastic insert from a standard 8-inch rain gauge, and a ruler graduated in tenths of an inch could be combined to form a snow water equivalent measurement system. By utilizing individuals or organizations who have a use for the data, a small network of observers can be developed, with the data benefitting both parties.

Algorithm Comparisons Between Existing and Proposed New Scanning Strategies Using Operational and Testbed WSR-88D Radars

Randy M. Steadham
Radar Operations Center, Norman OK

Rodger A. Brown
National Severe Storms Laboratory, Norman OK

National Weather Service (NWS) forecasters have been requesting radar scanning strategies, or volume coverage patterns (VCPs), for the WSR-88D that are faster and that have denser far-range coverage at lower elevation angles. In response to these requests, the Radar Operations Center (ROC) and the National Severe Storms Laboratory (NSSL) are developing new VCPs. Three of the proposed new scanning strategies for convective storms tentatively are called VCPs Beta, Gamma, and Delta. VCP Beta (12 unique elevation angles from 0.5-8.1º in 5 min) is designed to sample shallow and distant convection. VCP Gamma (14 unique elevation angles from 0.5-19.5º in 4.1 min) is a faster and denser (at lower elevation angles) version of current VCP 11 designed to sample deep convection. VCP Delta (tentatively completing 6 unique elevation scans from 0.5-6.5º in 2.3 min) permits scanning of fast-evolving damaging events such as tornadoes and microbursts. The lower elevation angles in these VCPs are separated by about 0.5º, as compared to the conventional 1.0º.

To test the efficacy of the new VCPs, output from the various storm algorithms were compared between testbed WSR-88Ds using the new VCPs and nearby operational WSR-88Ds using current VCP 11 or 21. Experiments were conducted in Oklahoma during 1999-2001 and along the Gulf of Mexico coast in Louisiana, Mississippi, and Alabama during 2002. In Oklahoma, comparisons were made between the operational KTLX radar in Oklahoma City and testbed KCRI (ROC) and KOUN (NSSL) radars in Norman. Along the Gulf coast, comparisons were made between the operational radars KLIX (New Orleans), KJAN (Jackson), and KMOB (Mobile) and "testbed radar" KBIX (Keesler Air Force Base, Biloxi) that the NWS recently acquired from the Air Force. Algorithm comparisons were made using storms that were roughly equidistant from pairs of radars. This study shows that comparable results were obtained from the new and current VCPs, with more consistent results frequently being produced by the new VCPs.

WSR-88D Program Issues

M. Vance Mansur
Radar Operations Center, Norman OK

I plan to discuss the Radar Operations Center's (ROC) organization, mission, services provided to the field, and future enhancements. The discussion will include:

- An overview of the WSR-88D system and network.
- The operations concept
- The maintenance concept
- WSR-88D support
- Top Five Hotline Problems (and their solutions)
- Open RPG (ORPG) status
- Upcoming ORPG builds
- Upcoming training impacts
- Open RDA (ORDA) status
- The interagency MOA
- Increased Wideband and Level 2 Data Rates
- Where To Get More Information

Mesoscale Models -- Issues of Resolution

Greg E. Mann
NOAA/NWS Detroit/Pontiac MI

Advancements in technology have resulted in rapid movement toward higher resolution numerical weather prediction models implemented at both National Centers and at local forecast offices. This collapse in resolution has been shouldered primarily on model architecture designed and constructed for super-mesoscale-b-scale atmospheric motions. This presentation offers a brief primer to mesoscale modeling and addresses some of the issues related to higher resolution simulations and its potential impact on operational forecasts. Furthermore, it offers some insight on model interpretation and utilization in the predictive realm. Finally, an alternate approach to short-term mesoscale prediction is presented.

Prediction of the Mesoscale Morphology of Winter Lake-Effect Circulations: Modeling and Observational Analyses

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University of Illinois
Urbana-Champaign IL

Idealized mesoscale model simulations were used to examine environmental and surface forcing factors controlling meso-b scale lake-effect (LE) snowstorms resulting from cold flow over an isolated body of water at mid-latitudes. Wind speed, lake-air temperature difference, ambient atmospheric stability, and fetch distance were varied across previously observed ranges. Simulated meso-b scale LE circulations occurred within three basic regimes (e.g., vortices, shoreline bands, widespread coverage), similar to observed morphological regimes. The current study found that the morphological regime of LE circulations could be effectively predicted using the ratio of wind speed (U) to maximum fetch distance (L). The ratio of U/L is equivalent to the inverse advective residence time of an air parcel over a lake and its relationship with LE morphology was found to be independent of the lake-air temperature difference (DT) for events with DT > 5/C. Lake-effect environmental conditions producing low values of U/L (i.e., approximately < 0.02 m s^{-1} km^{-1}) resulted in a mesoscale vortex. Conditions leading to U/L values between about 0.02 and 0.09 m s^{-1} km^{-1} resulted in the development of a shoreline band and U/L values greater than approximately 0.09 m s^{-1} km^{-1} produced a widespread coverage event. Additional results showed that transitions from one LE morphological regime to another in U/L parameter space were continuous and within transitional zones the structure of a LE circulation may contain features characteristic of more than one regime. Lastly, results will be discussed of an analysis performed using observational data and information from previously published Great Lakes LE studies to quantitatively evaluate of the U/L prediction method.

Operational Use of the RUC in the Great Lakes Area

Stan Benjamin
NOAA/FSL Boulder CO

A major revision to the Rapid Update Cycle, including 20km resolution, was implemented on 17 April 2002. A number of model and assimilation modifications were included in this revision that are significant for Great Lakes forecasting. Upcoming changes to the RUC now in testing at FSL, including land-surface/snow model changes, radar reflectivity and lightning assimilation, microphysics and convective parameterization improvements, and higher resolution will result in further improvements of the RUC for Great Lakes applications. Finally, a 10-km regional version of the RUC covering the Great Lakes area with forecasts out to 48h four times daily has been running since July and will continue through March (see http://ruc.fsl.noaa.gov/pig.cgi?TAQ+tl). These topics will all be discussed.

Short-range (0-48 h) Numerical Prediction of Convective Occurrence, Mode and Location in the Great Lakes Region

Paul J. Roebber and Michael A. Fowle
Atmospheric Science Group
University of Wisconsin at Milwaukee

A verification of high-resolution (6-km grid spacing) short range (0-48 h) numerical model forecasts of warm season convective occurrence, mode and location was conducted over the Lake Michigan region. All available days in the period 5 April through 20 September 1999 were evaluated using base reflectivity and accumulated precipitation products from the national radar network and the day one (00-24 h) and day two (24-48 h) forecasts from a quasi-operational version of the Pennsylvania State University – National Center for Atmospheric Research fifth-generation Mesoscale Model (MM5).

Contingency measures show forecast skill for convective occurrence is high, with day one (day two) threat score, equitable threat score, and Kuipers skill score of 0.84 (0.78), 0.69 (0.60) and 0.84 (0.75), respectively. Forecast skill in predicting convective mode (defined as linear, multicellular or isolated) is also high, with KSS of 0.91 (0.86) for day one (day two). Median timing errors for convective initiation/dissipation were within 2.5 hours for all modes of convection at both forecast ranges.

Forecasts of the areal coverage of the 24 h accumulated precipitation in convective events exhibited skill comparable to the lower resolution, operational models, with median threat scores at day one (day two) of 0.21 (0.24). When small displacements (less than 85 km) in the precipitation pattern were taken into account, median threat scores increased to as high as 0.44 for the most organized convective modes. A case example of an isolated convective event will be presented that illustrates some of the challenges associated with forecasting less organized convection. The implications of these results for the use of mesoscale models in operational forecasting will be discussed.

Verification of Precipitation Onset of the Eta Model for Convective and Non-convective Rain Events

Ernie Ostuno
NOAA/NWS Grand Rapids MI

The Eta model is verified for time of predicted onset of rain for widespread convective and non-convective precipitation events that affected southwest lower Michigan. The three runs prior to the event are compared to see how the margin of error changed as the event approached. Synoptic and meso-scale weather conditions attending each event are described and model performance for each event is evaluated on consistency of forecasts as well as accuracy. Data collection is currently ongoing during the late summer and early fall of 2002 for this study.

Marine and Coastal Weather Services
Vision for New Marine Products

Jamie L. Vavra
Marine and Coastal Weather Services Branch
Office of Climate, Water, and Weather Services
Silver Spring, MD

The Marine and Coastal Weather Services Branch, (OS21) of the Office of Climate, Water and Weather Services is responsible for managing the National Weather Service (NWS) marine and tropical prediction programs, and establishing the policy for these forecast products and services. An overview of the roles and activities of the staff of OS21 will be provided.

One of the primary objectives of this branch is to expand the baseline of marine products and services which are now provided to our partners and customers. New software, forecasting techniques, and technology being implemented at NWS forecast offices, the Interactive Forecast Preparation System (IFPS) provides the capability to prepare a local digital forecast database from which products in various formats can be generated.

Staff at selected NWS offices participating in the IFPS Rapid Prototype Project experimentally generate prototype products in gridded, graphical, and alphanumeric formats. Offices participating in the National Digital Forecast Database (NDFD) demonstration project are now routinely preparing gridded products such as wind and wave forecasts which are centrally collected and mosaiced into regional and national scale gridded products. Plans for inclusion of marine and tropical forecast weather elements in the NDFD will be presented. In addition, Marine and Coastal Services plans for the national implementation of new graphical and gridded marine and tropical products will be presented.

Development and Application of Operational Wind/Wave Relationship Guidance for Northern Michigan

Steve Rowley
Bruce Smith
NOAA/NWS Gaylord MI

NWS Gaylord prepares Nearshore Marine Forecasts (NSH) for 12 marine zones on 3 Great Lakes. Because of the complexity of the associated shoreline, fetch and wave heights can vary greatly from zone to zone, depending on prevailing wind. This tasked forecasters with manual calculations of wind/wave relationships for each marine zone, a process which added significant time to forecast preparation.

Recognizing the need for effective, consistent, operational guidance regarding local effects and wind/wave relationship guidance for each marine zone, the authors (1) measured maximum fetch lengths for 16 compass points of wind direction for each marine zone, (2) identified significant stretches of shoreline affected by local effects (such as funneling, channeling, and coastal convergence), and (3) complied this information in tabular format. Then, utilizing existing guidance relating wind speed, fetch, duration and significant wave heights, the authors developed color coded maps of significant wave heights, relating each compass point of wind direction to expected significant wave heights, for a 12 hour duration, for each marine zone, for wind speeds averaging 15, 20 and 25 knots.

Prior to the implementation of the Interactive Forecast Preparation System (IFPS), forecasters at NWS Gaylord routinely referred to these tables and charts when preparing forecasts. Anecdotal evidence suggests that this guidance (1) promoted a more efficient forecast preparation process by providing forecasters more time to assess wind direction and speed (more accurate wind forecasts translate to more accurate wave forecasts), and (2) promoted more consistent forecasts of significant wave height which appeared to be more accurate.

When NWS Gaylord began using IFPS, the wind/wave relationships were converted to “smart tools” that allowed forecasters to rapidly create grids of significant wave height from forecast wind fields. In the near future, WFO Gaylord forecasters will be able to compare this locally developed wave height output to model forecasts of wave heights from GLERL. Ideally, forecasts will incorporate the strongest aspects from both approaches to provide more accurate and detailed wave height forecasts for the nearshore waters of northern Michigan.

Great Lakes Water Levels

Keith Kompoltowicz CELRE-HH-W
U.S. Army Corps of Engineers
Detroit MI

The Great Lakes-St. Lawrence River system is a dynamic and still evolving environment. Great Lakes water levels have fluctuated dramatically since the last glaciers retreated over 10,000 years ago. These fluctuations differ in frequency and magnitude and are hard to accurately predict.

Natural impacts of water levels include weather patterns in the Great Lakes region, while man-made factors are dredging, dams and regulated outflows in parts of the system. Changes in weather patterns, dredging and regulation strategies can drastically change water levels.

Near record high water levels in 1997 quickly dropped to the lowest levels in 30 years by 2000. Levels slightly increased in 2001 and by a larger magnitude in 2002. Even with these increases, the lakes are still below their long-term averages. Forecasts into 2003 continue to show below average lake levels.

Extended Forecast Verification at WFO Gaylord, MI

Patrick Bak
Bruce Smith
NOAA/NWS Gaylord MI

A few years ago, the National Weather Service (NWS) expanded the time period covered by it's Zone Forecast Product from five to seven days. This was done in response to improvements in numerical modeling, and the desire to provide additional forecast information to the public. In this presentation, the accuracy of 3 to 7 day forecasts provided by NWS Gaylord from January 2000 to present will be examined. Forecasts were compared to model guidance (FMR) to see what degree of improvement forecasters were able to provide over model guidance. In addition, since multiple years of data were collected, year to year trends were examined to determine whether forecasters are becoming more skillful at 3 to 7 day forecasting.

Human and model derived temperature forecasts for Alpena were verified against the official daily high and low temperature measured at the Alpena County Regional Airport. Precipitation forecast data consisted of office forecasts of "wet" versus "dry" over northern lower Michigan, verified against whether measurable precipitation (with approximately 30% coverage) occurred across northern lower Michigan.

A number of statistics were calculated. Of particular interest, it was found that forecasters were at least somewhat skillful when selectively making "large" deviations from the FMR temperature guidance. In addition, improvement was noted in both temperature and precipitation forecasts between 2000 and 2001.

Nocturnal Convection and its Relation to the Low Level Jet in the Great Lakes Region

Timothy Halbach and Paul J. Roebber
Atmospheric Science Group
University of Wisconsin at Milwaukee

Research has indicated that convective rainfall most frequently occurs between midnight and 7:00 am (local time) in the western Great Lakes region. This study seeks to investigate the origins of this nocturnal maximum. The Low Level Jet (LLJ) has been linked to nocturnal convection in other regions. Analyses of observations and model data show that a similar relation exists in Southern Wisconsin. For the warm season (May through August) of 1999, there were 26 convective precipitation events in southern Wisconsin. EDAS (Eta Data Assimilation System) data show that a LLJ was present in southern Wisconsin on 20 of those 26 days (77% of the events). ACARS (Aircraft Communications, Addressing, and Reporting System) data were used to confirm the model results. Hence, accurate forecasts of convective precipitation will depend on reliable forecasts of the evolution of the LLJ. Current understanding of LLJ dynamics, however, is largely confined to the southern Plains region. Preliminary research addressing the dynamics of the LLJ in the Great Lakes, including model-based diagnostics, will be presented.

The Role of Mid-Level Jet Intensification in the 21 July 2002 Upper Michigan Convective High Wind Event

Kevin Crupi
NOAA/NWS Marquette, MI

During the late afternoon and evening of 21 July 2002, a line of severe thunderstorms produced wind gusts estimated over 45 ms-1 (100 mph) and caused extensive damage in a band across central Upper Michigan. The interaction between an intensifying mid-tropospheric jet streak over an approaching frontal zone -- which enhanced mid-level dry advection into Upper Michigan -- and very moist and unstable low-level air in place was instrumental in causing these climatologically rare convective wind gusts over Upper Michigan.

The 9 April 2001 Severe Weather Outbreak

Rodney Smith
Angela Lese
NOAA/NWS Syracuse IN

On the early evening of 9 April 2001, severe weather moved through the southern portion of the Northern Indiana National Weather Service County Warning Area(CWA). The majority of the severe weather was associated with two distinct supercells, which produced golfball to softball size hail and funnel clouds but no tornadoes.

On the afternoon of 9 April, a stationary front was across northern Illinois, Indiana, and Ohio. South of the front the airmass was moderately unstable, with the 0000 UTC Lincoln Illinois (ILN) upper-air sounding showing a surface based LI of -7, and a CAPE of nearly 2500 J/kg. Surface to 6km shear was near 60 kt, indicating support for supercell formation, however surface to 3km Storm Relative Helicity (SRH) of near 80 $m^2 s^{-2}$ was not favorable for tornado formation. Low pressure developing along the front in Missouri had generated a mesoscale convective system (MCS) over Wisconsin overnight that moved across Michigan and Lake Erie into Pennsylvania by late afternoon of 9 April. As this MCS moved east, it generated an outflow boundary which moved south ahead of the main surface front as a wind shift.

Thunderstorms initiated over the western end of the outflow boundary across the southwest corner of the CWA by 2100 UTC 9 April. These storms intensified as they moved east along and north of the outflow boundary, and were producing severe hail by 2230 UTC. At this time the storms began showing increasing rotation in the low and mid levels. The WSR-88D TVS algorithm began detecting deep rotation, mainly within two distinct supercells, with some TVS depths over 20000 ft and bases below 5000 ft. Bounded Weak Echo Regions (BWER) were seen in reflectivity cross sections from the WSR-88D. Operator defined mesocyclones were weak to moderate at this time on the WSR-88D 0.5 deg SRM as per the OSF mesocyclone nomograms. By 0030 UTC 10 April, the storms had moved into the southeast CWA and rotation had strengthened, with strong operator defined mesocyclones detected, and continued deep TVS. An appendage or hook was also observed with one of the supercells. Up to softball size hail was reported over the southeast CWA along with numerous funnel cloud reports, but no confirmed tornadoes touched down. This case study will present an analysis of the radar data and storm environment to show the structure of the storms, and present clues the forecaster may have had in real time to determine lack of tornadogenesis, and post mortem findings that may lead to a better explanation of the lack of tornadogenises.

The May 21st 2001 Tornado Outbreak

Randy Graham
NOAA/NWS Grand Rapids MI

On May 21st, 2001 southwest Michigan experienced a record breaking tornado outbreak. As an upper level trough moved east through the northern plains a warm front lifted north into lower Michigan. As the warm front approached widespread low topped convection developed and moved into southern lower Michigan. The low level winds backed sharply in a narrow region north of the warm front resulting in increased low level helicity values in the 0-1 km layer. Strong surface based instability was present north of the warm front with very low LFC heights aiding the ingestion of low level vorticity into the updrafts. As the storms interacted with the boundary they rapidly developed rotation and during the afternoon hours eighteen tornadoes touched down in southern Michigan with 15 occurring in the Grand Rapids County Warning Area (CWA).

While the tornadoes themselves were not significant in intensity (only one was an F2 or greater) the shear number of tornadoes that developed that afternoon make this event particularly noteworthy. This brief case study will review the environment in which the tornadoes developed highlighting a few important precursors to the event. The presentation will also focus attention on important radar signatures and stormscale analysis of some of the tornadic storms.

The Lansing F1 Tornado – September 9, 2001

Rob Dale
WLNS TV-6 Lansing MI

The primary concern in Mid-Michigan for severe weather on September 9, 2001 appeared to be tornado activity, until several small squall lines developed in west Michigan with reports of wind damage. However a small supercell developed just southwest of Lansing which triggered the Baron's rotating (shear storm) algorithm, and an F1 tornado touched down moments later. This presentation will look at the change in expected severe weather during the event, as well as a close-in view from a live television radar just a few miles away from the tornado.

The 24 October 2001 Tornado Outbreak

Jeff Logsdon, John Taylor, Pat Murphy, Sam Lashley, Rodney Smith and Kevin Barjenbruch
NOAA/NWS Syracuse IN

The second largest tornado outbreak on record occurred on 24 October 2001 over the Northern Indiana National Weather Service County Warning Area (CWA) which covers northern Indiana, southwest lower Michigan and northwest Ohio. Ten distinct tornadoes touched down, including two rated F3 on the Fujita scale. This tied with the Palm Sunday Outbreak of April 1965 and only the Super Outbreak of April 1974 rates higher in the number of tornadoes for this area.

Although the pattern was more reminiscent of early spring and a rare occurrence for late October, nearly ideal atmospheric conditions were in place for the development of severe weather. The synoptic pattern on 1200 UTC 24 October 2001 showed a surface low over northern Minnesota with a 500mb closed low over North Dakota. An intense cold front extended south from the low across Wisconsin, western Illinois and central Missouri down to a second low over the northeast corner of Oklahoma. The special 1800 UTC sounding taken at Lincoln Illinois (ILN) indicated a 65kt low-level jet at 700mb over east-central Illinois. The 0000 UTC sounding from Detroit revealed a moderately unstable and weakly capped atmosphere with CAPE = 1000J/kg and
LI = -6. By 0000 UTC 25 October 2001, the 500mb low had deepened and become negatively tilted as it moved into eastern Minnesota. This resulted in height falls in excess of 100m over the CWA and the nose of a 100+kt jet pushing into the region. This further de-stabilized the atmosphere over the area during the afternoon hours as the surface cold front surged into the area.

By 1900 UTC 24 October 2001, a squall line had formed along the cold front from northeast Illinois down through southwest Missouri. Analysis of surface observations showed a mesoscale low had formed along the cold front near Champaign Illinois at 1800 UTC, which intensified as it moved into western Indiana. This caused an increase and backing of the surface winds near the squall line which significantly increased the low level shear and storm relative helicity and provided a favorable environment for tornado development within the squall line. As the northern end of the squall line moved into northwest Indiana, a Line Echo Wave Pattern (LEWP) formed consisting of two strong bow echoes with strong cyclonic shear just north of the apex. The resulting tornadogenesis occurred just northwest of the apex of the bow echoes in the southeast portion of the comma head. One additional tornado occurred later over northwest Ohio as the squall line merged with a minisupercell which had formed out ahead of the squall line. This paper will present a detailed analysis of radar data and near-storm environment data to explain the structure of the storms that produced the tornadoes and add to existing research that provides the best method for identifying potential tornadic storms that are embedded within a squall line.

The August 1 2002 Northern Michigan Tornadoes

Bruce Smith
NOAA/NWS Gaylord MI

Several waves of severe weather impacted northern Michigan on August 1, 2002. Not surprising, the atmosphere was "primed" -- both dynamically and thermodynamically -- for severe weather on this day. In addition to providing a general overview of the synoptic setting which lead to this severe weather event, this presentation will offer some insights regarding the impact of both synoptic and meso-scale processes which lead to two tornadic events.

It appears that with both tornadoes, a subtle wind shift line (or "pseudo-warm front") played a key role in initiating tornadogenesis (by providing additional low-level horizontal vorticity). The development and persistence of this wind shift line appeared to be tied to rain-cooled air resulting from persistent showers across the northern Great Lakes. Boundary layer shear (veering winds with height) in the vicinity of the "pseudo-warm front" appeared to be further enhanced by an approaching surface pressure fall center associated with the synoptic wave.

This event reemphasizes the need for continuous meso-analysis during severe weather events. It is only through the detailed analysis of the near storm environment that the interaction between small synoptic scale features and storm scale processes can be accurately anticipated.

The August 1st 2002 series of Bow Echo Storms across the Central Great Lakes as seen by the new Canadian Radar processing System

Michael Leduc
National Radar Project
Environment Canada
Downsview Ontario

In the 24 hour period beginning 0800z August 1 2002, a series of at least 3 fast moving bow echoes swept across the Central Great Lakes . There were numerous reports of wind damage in a 100 km wide path from eastern upper Michigan to north of Lake Ontario . There were several reports of blow downs ranging from a few hectares to a couple of square kilometers. One person was killed by a falling tree north of Lake Ontario.

This paper will look at the meteorology of this situation, concentrating on the radar assessment of the storm. In particular we will look at the utility of the new Canadian radar software in diagnosing this event. For some portions of this event the damaging storms were seen at similar distances by both WSR 88 and Canadian radars. This case offers up the possibility of comparing the outputs from the

WSR88 and those from the Canadian system.

The Medium and Large Scale Environments Associated with Severe Rainstorms in Ontario

Brian P. Murphy
Meteorological Service of Canada
Burlington, Ontario

The accurate prediction of “High Impact” weather events is of vital importance to the Meteorological Service of Canada (MSC). With the goal of increasing the capability to anticipate their occurrence in Ontario, several recent severe rainstorms have been studied in an effort to better understand their characteristics including meteorological precursors, circulation patterns and rainfall distributions. Most of these events occur with well organized mesoscale convective systems (MCS), often in seemingly innocuous synoptic scale meteorological settings.. It is hoped that operational meteorologists in Ontario can use the results from the study of these storms and their classification to subjectively anticipate their development and scope.

Heavy Rainfall - June 9-11, 2002
The Northern Minnesota, Southeastern Manitoba, and
Southern Northwestern Ontario Flooding Event

James Cummine and Brian Murphy
Meteorological Service of Canada**,** Environment Canada

A severe flooding event occurred over southern portions of Northwestern Ontario and southeastern Manitoba along with northern Minnesota when a series of synoptic scale and mesoscale meteorological forcing processes came together and caused persistent rainfall from the evening of June 9 through the early morning hours of June 11, 2002. Two day rainfall totals approaching 300 mm were reported from official and volunteer network rain gauges in the vicinity of the Canada - United States border resulting in extensive flooding and property damage. The mesoscale convective storms and the processes which generated the MCS which caused the flooding in northern Minnesota, southern Manitoba and southern Northwestern Ontario will be the focus of this presentation.

There are a number of ways in which heavy rainfall can occur. Simply, the heaviest rainfall amounts occur when the highest rainfall rates occur for the longest duration. Precipitation rate and duration are two key components. Storm size and motion help to determine duration while precipitation efficiency is a key component to determining precipitation rate. Once deep moist convection is initiated, cell propagation and motion are key components to rainfall duration. Stability, vertical velocity and moisture are key components to determine rainfall rate. The way in which these components come together can transform an otherwise ordinary rainfall into an extraordinary life-threatening situation.

At 1200 UTC 9 June 2002, a west to east surface frontal boundary was located from North Dakota across northern Minnesota and Wisconsin and remained nearly stationary over the next 48 hours. The synoptic flow was very similar to that proposed by Maddox as favourable for MCC formation with a weak upper ridge and a strong moist southerly low level flow. The boundary provided the focus for an extended period of elevated convective storms to develop while the low level flow continued to feed moisture into the area. Rainfall rates approached 75 mm/hr from cells embedded in the MCS. The interaction between the synoptic forcing and the mesoscale forcing determined the rainfall intensity, cell motion and cell propagation of the MCS.
A given rainfall event's chance to produce a flood are dramatically affected by such factors as antecedent precipitation, the size of the drainage basin, the topography of the basin and other hydrologic factors. However, this presentation will focus on the meteorological characteristics associated with heavy rainstorms, along with a detailed description of the meteorological conditions associated with the record rainfalls from the storms on 9-11 June 2002.

Lake Effect Thunder-Snows Over the Eastern Great Lakes

Bob Hamilton
NOAA/NWS Buffalo NY

Heavy lake effect snows typify winter weather across Western New York as intrusions of arctic air generate snowfall amounts that are often measured in feet. While significant snowfall is produced from these events, they are usually very localized in areal coverage.

These impressive mesoscale events are occasionally highlighted by thunder and lightning. Heavy snowfall of 2 to 4 inches an hour are common during such convective outbursts. Without the snow-muffled rumbles of thunder, these unusual electrical events can easily be mistaken for sparking power lines or storm damaged transformers.

Lightning-bearing lake effect snows across Western New York typically occur early in the winter season. The surface temperature of Lakes Erie and Ontario are still relatively "warm" at that time of the year. In addition, the depth of the surface to -10C layer is still several thousand feet thick. Higher lake temperatures and a deep boundary layer appear to be critical components that allow for super cooled water droplets to generate graupel, which in turn is crucial for electrical charge separation.

Current electrification models strongly support the theory that graupel production in the -10C to -20C layer is essential for the beginning stages of lightning production. The collision of graupel with smaller ice particles produces the needed charge separation needed for lightning to take place.

This research has been conducted using 4 years worth of sounding and ETA model data, dating from the winter of 1996-97 through 2001-2002. Results of our study on Western New York storms suggest that if the depth of the surface to -10C is too shallow then graupel cannot be produced and lightning is much less likely. Various other convective parameters such as vertical velocity, CAPE and equilibrium level are also examined to determine their possible contribution to lightning production in lake effect snow.

Simulation of Cloud Bands Associated with Lake Effect Snowstorms

G.W.K. Moore
Anthony Liu
University of Toronto

K. Tsuboki
Nagoya University

Cloud bands or cloud streets associated with lake effect snowstorms are an enigmatic atmospheric phenomenon. This is the result of their small length scale, their dependence on the background environment and the complex microphysical interactions that are active within them. We will present numerical simulations of these bands that have been performed with a cloud resolving model developed at Nagoya University. Three-dimensional simulations were performed at very high spatial resolutions (~500m in the horizontal and ~25m in the vertical) in a domain of sufficient size so as to allow for the development of multiple cloud bands. In this talk, we will discuss the non-linear interaction that exists between the cloud bands and the background environment wind profile. The vertical momentum transport associated with this interaction
can result in an acceleration of the surface wind field and a concomitant increase in the magnitude of the surface fluxes of sensible and latent heat. We will also discuss the production of snow and graupel in the cloud bands.

Assessing the Impact of Great Lakes Water Temperature Fields on Snowfall Production Using the Work Station Eta Model

Tom Niziol
NOAA/NWS Buffalo NY

This study investigates the impact that changes in the initialized Great Lakes water temperature fields have on model solutions of snowfall to the lee of the Great Lakes. Lake effect snows develop as a direct result of the flux of heat and moisture from the warm waters of the Great Lakes into a cold airmass. When using a mesoscale numerical model to predict these events, it is important therefore to begin with the most accurate water temperature data set as possible. Currently, Great Lakes temperatures are derived from NOAA polar orbiter satellites. Unfortunately, when the skies are cloudy over the Great Lakes, the satellite cannot measure the lake temperature directly and instead a smoothing process is employed to derive the temperature field.

In our preliminary study, we compared output from the work station eta model by simply changing the overall water temperature of the lakes by a few degrees. Model snowfall forecasts showed significant differences for small changes in the overall temperature field over the Great Lakes.

The implementation of mesoscale models within National Weather Service offices, universities, and private industry continues to expand on an annual basis. The advantages of locally run models include the ability to define resolution, domain, various parameterizations and model output specifically for the local forecast problem. Although there are distinct advantages to running mesoscale models, the literature contains many documented cases concerning the limitations and assumptions that such models possess. It is more important than ever therefore that users understand the impacts that these assumptions and limitations can have on our forecast products.

Lake-effect Snowstorms Associated With Synoptic-scale Cyclones over Southern Ontario

A. Q. Liu and G.W.K. Moore
Department of Physics
University of Toronto
Toronto, Ontario

Lake-effect snowstorms are an important source of severe winter weather over the Great Lakes region that are often triggered by the passage of a synoptic-scale cyclone. In this talk, we develop a climatology of lake effect snowstorms and cyclone trajectories over southern Ontario for the period 1992-1999. As we shall show, the passage of a synoptic-scale cyclone is a necessary but not sufficient condition for the development of intense lake-effect snowstorms. In particular, we show that intense lake-effect snowstorms are associated with cyclones that track towards the northeast. Cyclones that track towards the east, the most common trajectory in the winter months, typically do not result in the development of intense lake-effect snowstorms. The synoptic environment associated with these two classes of cyclone trajectory will be investigated to understand the reasons for the difference in outcome vis-à-vis lake-effect snowstorms.

Synoptic and Meso-scale Aspects of a Significant Lake Enhanced Snow Event in Northern Michigan

Jeff Zoltowski
Bruce Smith
NOAA/NWS Gaylord MI

A prolonged lake effect/enhanced snow event occurred across northwest lower Michigan between December 24 and December 30, 2001. Snowfall totals ranged as high as 78 inches during this event. The synoptic set-up for this snow event was dominated by a slow moving 500 mb low over southern Canada, which retrograded during the period in question. Westerly cyclonic flow in the low levels of the atmosphere, coincided with favorable thermodynamics and over water instability, to produce an unusually persistent lake effect snow event.

The events of the early morning of December 29 will be examined closely. The unexpectedly quick passage of a lake-aggregate surface trough to the south of Grand Traverse Bay, produced a surprise heavy snow event for the Traverse City area. It is hypothesized that local diurnal effects, and an inaccurate model forecast of 850 mb temperatures in the northern Great Lakes basin, contributed to poor model performance regarding the evolution and movement of the lake aggregate surface trough.

The Effects of Topography on Snowfall in Upper Michigan

Thomas Hultquist
NOAA/NWS Marquette MI

The Upper Peninsula of Michigan is characterized by significant variations in topography, with changes in elevation of greater than 400 m (~1300 ft) over distances of fewer than 14 km (~ 9 mi). These changes in topography result in widely varying snowfall amounts across Upper Michigan. Observations provide some information on the variability of snowfall, but low population density and the resultant lack of reliable observers make it difficult to infer a great deal about the variability of snowfall from observations alone. As a result, forecasters are forced to make non-specific general statements about the enhancement of snow amounts in higher elevations. In order to provide more useful and accurate forecast information, a clearer understanding of the topographic enhancement to snowfall in Upper Michigan was needed.

A mesoscale model was employed in an effort to better understand and quantify the effects topography on snowfall in Upper Michigan. The Regional Atmospheric Modeling System (RAMS) was used to test the sensitivity of various meteorological parameters to topography in the National Weather Service (NWS) Marquette County Warning and Forecast Area (CWFA). Three events were chosen from the 2001-2002 Winter season to represent three basic Winter storm regimes: Non-Lake Effect, Lake Enhanced, and Pure Lake Effect. These regimes characterize three basic boundary layer stability situations which can be present across Upper Michigan during the Winter season. It was felt that an examination of these cases would prove useful, since the effects of topography on atmospheric motions in the boundary layer are primarily the result of air flow relative to the topography and stability. In order to isolate the effects of topography, four model simulations were conducted for each case: Control, No Topography, No Lake, No Lake/Topography. The simulations were conducted in a nested configuration which allowed for a maximum resolution of 500 m on the innermost nest(s). Preliminary results from these simulations are presented to illustrate the significant impact topography has on the spatial distribution and intensity of snowfall across Upper Michigan in varying stability regimes.

The 1 March 2002 Upper Michigan Heavy Snow Event:
Utility of a Local Mesoscale Model in the Forecast Process

James Sieveking
NOAA/NWS Marquette MI

On 1 March 2002, 30-35 cm of snow accumulated across the Keweenaw Peninsula, Huron Mountains, and the higher terrain outside of Munining in the Upper Peninsula of Michigan. A mesoscale vortex formed along an arctic cold front and associated trough of low pressure over western Lake Superior during the early afternoon. An intense zone of convergence and associated lake effect snow band became stationary along the lakeshore across extreme northern Upper Micghian, where snowfall rates of up to 10 cm per hour were observed. Visibility was reduced to zero at times within the heaviest snow bands.

An operational version of the Workstation Eta model run twice daily at the National Weather Service office in Marquette proved valuable to forecasters in identifying mesoscale features and areas of orographic enhancement during this event. Parameters such as moisture convergence, frontogenesis, and terrain induced omega not only aided in identifying the location and timing of the snow band, but also where the most intense snow would occur. This event also highlights the difficulty and constraints forecasters can face when determining winter weather headlines due to the limited areal coverage of warning criteria snowfall which occurred.

An Analysis of an Unexpected 12 inch Snowstorm Across Southern New York State

Michael L. Jurewicz, Sr.
Michael Evans
NOAA/NWS Binghamton NY

During the afternoon and early evening hours of 19 January 2002, a narrow band of heavy snowfall affected portions of northern Pennsylvania and southern New York. This band was roughly 30 kilometers wide, with the most intense and persistent snowfall rates oriented west to east from near Elmira, NY across the Binghamton, NY area, then further eastward into the Catskill mountain region. Storm totals of 8 to 12 inches in about a 6 hour period were common within this small corridor.

This event had some unique characteristics that likely contributed to its “surprise” nature. First, the prevailing flow pattern was flat and progressive as indicated by observed upper air and well initialized model data. This led to weak patterns of vorticity and thermal advection at levels where standard meteorological analysis are typically performed. Second, a strong upper level speed maximum was located from New York state into southern New England, with the more favorable entrance region of this upper level jet core across the Mid-Atlantic region, well south of the heavy snow band. Third, despite uniform liquid equivalent precipitation totals (generally 0.20" to 0.30") observed across New York and Pennsylvania for this event, actual snow accumulations varied widely across the region. Interestingly, the models’ quantitative precipitation forecasts (QPF) were consistent and fairly accurate.

So why did heavy snow develop? A cross-sectional inspection of observed and model data during the time of heavy snowfall revealed a frontal boundary that sloped upward from south to north, with the northern extent of the front located across New York and Pennsylvania. Strong frontogenetical forcing in mid-levels of the atmosphere was associated with the frontal zone over southern New York. Additionally, pronounced diffluence developed just above the zone of frontogenesis as the area came under the exit region of a 500 mb jet streak moving through the central Appalachians. This juxtaposition created a shallow, but vigorous circulation promoting strong lift between 600 and 500 mb. Cross-sectional analysis also revealed an area of weak conditional instability in a shallow layer just above the frontal zone, near 500 mb. This instability would have acted to enhance and localize the circulation associated with the frontogenesis, and could have resulted in localized areas of convection, reinforcing the intensity of the banded feature associated with frontogenesis. Finally, another key contributor to the heavy snow appeared to have been a thermal structure supportive of favorable snow growth mechanisms within a deep and saturated layer. This aspect was well portrayed by hourly sounding profiles. It is theorized that each of the above factors played a significant role, with the absence of any one of them possibly resulting in far less snowfall.

This case study showed the potential value of viewing model fields using cross-sections. Particularly when mechanisms of interest are shallow in nature, they could fall between mandatory or significant levels or be “smoothed out” if looking at a mean layer in plan view.

A Compare and Contrast Study of Two Banded Heavy Snow Events

Michael Evans
Michael L. Jurewicz, Sr.
NOAA/NWS Binghamton NY

Snow developed across central and northeastern Pennsylvania during the late afternoon on January 6th, 2002 as a major storm developed along the mid-Atlantic coast. Localized, narrow bands of heavy snow developed within the main snow shield, and produced total snow accumulations of 10 to 20 inches across a region from central Pennsylvania through eastern New York. The storm developed as an intense, compact mid-tropospheric short-wave trough lifted northward along the East Coast downstream from a major long-wave trough located over the Mississippi Valley. This study will compare and contrast that storm to a second storm that produced a single band of heavy snow across northern Pennsylvania and southern New York on January 19th. Snow accumulations within that band reached up to 12 inches across the southern tier of upstate New York. In contrast to the storm on January 6th, the storm on the 19th was associated with a relatively weak area of low-pressure, and a flat, progressive mid-tropospheric flow pattern.

The most striking similarity between the storm on January 6th and the storm on January 19th was that localized bands of heavy snow developed and played havoc with snowfall forecasts. A comparison of the observed and model forecast data from both storms indicate that in both cases, the heavy snow bands developed in areas where the quasi-geostrophic forcing for upward motion was relatively weak. In the case on the 6th, a pronounced maximum of quasi-geostrophic forcing for upward motion was indicated, however the maximum was south of the heavy snow area. On the 19th, strong, organized areas of quasi-geostrophic upward motion forcing were completely absent. In both cases, the heavy snow developed in association with frontogenesis associated with frontal boundaries that sloped upward from south to north across Pennsylvania and southern New York.

Cross-sectional analysis of each event indicated that the snow banding in both cases was likely enhanced by instability located along and just above the sloping frontal boundary. In the case on January 19th, a cross-sectional analysis of theta-e indicated that conditional instability was present above the frontal surface. By contrast, in the case on January 6th a cross-sectional analysis of theta-e indicated a relatively stable environment above the frontal surface. In that case, evidence is shown that the environment near the heavy snow bands may have been associated with inertial instability in the geostrophic wind field. The resulting horizontal accelerations, as the real wind field attempted to adjust to this unstable condition, could have resulted in areas of slantwise convection. It is hypothesized that the small scale of the mid-level short-wave trough with this event was associated with very sharp downstream ridging, which resulted in the inertial instability.

As was the case with on January 19th, the data shown for this case indicates the importance of utilizing cross-sections when diagnosing model data associated with a potential snowstorm. Comparing and contrasting the data from January 6th and January 19th also illustrates that a variety of environments can produce banded snowstorms.

Improving Snowfall Forecasting by Diagnosing Snow Density

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Atmospheric Science Group
University of Wisconsin at Milwaukee

David M. Schultz and John V. Cortinas Jr.
NOAA/National Severe Storms Laboratory

Current prediction of snowfall amounts is accomplished either by using empirical techniques or by using a standard modification of liquid equivalent precipitation such as the ten-to one rule. Unfortunately, measurements of freshly fallen snow indicate that the snow ratio can vary on the order of 3:1 to (occasionally) 100:1. Improving quantitative snowfall forecasts requires, in addition to solutions to the significant challenge of forecasting liquid precipitation amounts, a more robust method for forecasting the density of snow.

A review of the microphysical literature reveals that many factors may contribute to snow density, including in-cloud (crystal habit and size, the degree of riming and aggregation of the snowflake), sub-cloud (melting and sublimation) and surface processes (compaction and snowpack metamorphism). Despite this complexity, this research explores the sufficiency of surface and radiosonde data for the classification of snowfall density. A principal component analysis isolates seven factors that influence the snow ratio: solar radiation (month), low- to mid-level temperature, mid- to upper-level temperature, low- to mid-level relative humidity, mid-level relative humidity, upper-level relative humidity, and external compaction (surface wind speed and liquid equivalent). A ten-member ensemble of artificial neural networks is employed to explore the capability to determine snow ratio in one of three classes: heavy (1:1<ratio<9:1), average (9:1=ratio=15:1), and light (ratio>15:1). The ensemble correctly diagnoses 60.4% of the cases, which is a substantial improvement over the 41.7% correct using the sample climatology, 45.0% correct using the ten-to-one ratio and 51.7% correct using the National Weather Service "new snowfall to estimated meltwater conversion" table. A key skill measure, the Heidke Skill Score, attains values of 0.34-0.42 using the ensemble technique, representing increases of 75-183% over the next most skillful approach. The Critical Success Index shows that the ensemble technique provides the best information for all three snow-ratio classes.

Waterspouts Structure, Wind Speeds, and Forecasting

Dr. Joe Golden
NOAA/FSL Boulder CO

A review of 35 years of waterspout research will be given, using primarily field data gathered from the world's waterspout capital, the Florida Keys. Emphasis will be given on structure, including windspeeds and life-cycle, linkages to tornadoes, and forecasting methodologies. Suggestions will be made on appropriate language and timing for warnings and verification issues over the Great Lakes and elsewhere.

Waterspouts over the Great Lakes: What we can see

Wade Szilagyi
Meteorological Service of Canada, Environment Canada

Research into waterspout activity over the Great Lakes has been continuing at the Meteorological Service of Canada since 1994. An integral part of this research has been the collection of photographic evidence. Thus far we have collected 60 photographs as well as 6 videos. With the popularity of the video camera as well as the growing population around the Great Lakes, the likely hood of waterspouts being photographed in the future will increase.

This presentation will include a sample of the more dramatic photos/videos taken. Also, a brief discussion of waterspout dynamics will be included.

FSL Research and Projects Update

Dr. Joe Golden
NOAA/FSL Boulder CO

A short review of ongoing research in the Forecast Systems Laboratory will be given, with updates on AWIPS and the proposed transition to LINUX, as well as IFPS, GAINS, FX-NET/FX-Collaborate and the WRF mesoscale model development.

Policy and Preparedness for Local Damage Surveys and Other Investigations

Peter Chan
WXMI FOX 17 TV, Grand Rapids MI
(formerly NOAA/NWS Grand Rapids MI)

Operational meteorologists may be required to conduct damage surveys to document the occurrence and impact of severe weather events that result in significant property damage, injuries, and/or fatalities. On rare occasions, special investigations or the support thereof, for major weather disasters, marine and air disasters or other unusual phenomena may be necessary. Unfortunately, little if any formal training is available concerning the methodology of conducting damage surveys let alone developing office policy and preparedness for such matters. Major weather events tend to generate significant and potentially overwhelming media attention. Furthermore, such situations can require working with other agencies at the local, state and federal levels, some of which may be conducting investigations of their own. In any case, a coordinated and consistent response by a forecast office is necessary to ensure that the meteorological and operational circumstances surrounding an event are portrayed as accurately as possible. It becomes even more important if warning procedures come under scrutiny. This presentation will address these concerns and attempt to offer a blueprint for developing sound policy and being prepared.

The Increased Verification of Severe Thunderstorms (INVEST) Program: Training for Damage Surveys

Ernie Ostuno
NOAA/NWS Grand Rapids MI

Verification of severe weather warnings is a top priority of the National Weather Service. Unfortunately, thorough ground surveys are time and labor intensive and are usually not done unless major damage has occurred. Many, if not most, marginal storm damage reports are not investigated with ground surveys. The goal of this program is to increase the scientific integrity of the severe weather verification program by providing training to members the county emergency management agencies (EMAs) or SKYWARN spotters who are interested in performing ground surveys of damage from severe storms in their local area. The training consists of two main parts. Part One covers estimating wind speeds from structural damage from the Fujita Scale as well as focusing on tree damage, which is quite often the only damage that occurs from marginally severe events. Part Two covers differentiating tornado and microburst wind damage, showing examples of both. It is hoped that more accurate wind speed estimates from comprehensive ground surveys, combined with reviews of the radar data and near storm soundings, will lead to a better understanding among forecasters of what radar signatures and thresholds produce severe weather under various environmental conditions, and therefore lead to better warnings.

Grand Rapids Winter Storm Climatology

Randy Graham
NOAA/NWS Grand Rapids MI

A variety of different storm tracks and evolution's can bring heavy snow to southwest lower Michigan. The goal of this study was to identify synoptic scale patterns and storm tracks which are favorable for bringing heavy snow to southwest lower Michigan. This information could then be used to assist in the forecast process and to help with better long lead outlooks and recognition of potentially heavy snow events. Once synoptic patterns have been identified focus can then be placed on the mesoscale processes which typically produce the heavy snow.

A heavy snow event for this study was defined as an event in which six or more inches of snow fell in Grand Rapids in a period of 24 hours or less. Nearly 60 cases were identified for the study encompassing the time frame from 1965-1994. The events were then examined individually to identify common patterns that produced the heavy snow events. Six primary patterns were identified: Southern Plains Lows, Alberta Clippers, Colorado Lows, Hybrid Lows, Gulf Coast Lows, James Bay Lows/Troughs. After all of the cases had been examined composite maps of MSLP, 850 mb temperatures, 850 mb winds, 500 mb heights, and 250 mb winds were generated for each pattern type. This presentation will briefly cover the frequency, monthly distribution, and evolution of the different synoptic patterns associated with heavy snow events in Grand Rapids.

Classifying Lake Effect Snow Storms

Jim Kosarik
NOAA/NWS Cleveland OH

Work has been done on classifying winter storms by category (Zielinski 2002). Categories are from one to five with one being weak and five being powerful. The classification scheme is beneficial from a meteorological perspective by predicting the impact likely to occur from an upcoming storm or assessing the impact of a storm from a historical perspective.

The storms in the study include nor'easters as well as some Colorado lows that became powerful Great Lakes storms. The storm classification is based strictly on synoptic parameters and forward speed. This approach will not work on lake effect snow storms due to their mesoscale nature. A different classification scheme is needed to categorize lake effect snow storms.

Potential mesoscale parameters that may be useful in categorizing lake effect snow storms will be discussed as well as the amount of social impact that needs to be taken into account. Regional adjustments may be needed to storm categories. Storms from the upcoming season (2002-'03) will be documented and categorized as well as some historical storms. The results will hopefully determine whether there may be utility in categorizing storms for inclusion in statements to the general public.

A Climatology of Northern Michigan Tornadoes

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A climatological study of known tornadoes that have occurred across northern lower Michigan and eastern upper Michigan since1950 was conducted in an effort to determine the spatial and temporal variability of these storms. The County Warning Area (CWA) of the Gaylord, Michigan National Weather Service forecast office (APX) encompasses 25 counties across eastern upper and northern lower Michigan with a population of approximately 600,000. All data used in this study was obtained through the National Climatic Data Center and the Storm Prediction Center. Both the spatial and temporal distribution of all tornadoes were examined; whereas, only the temporal distribution of tornado days and tornado intensity were studied.

Preliminary results indicate that the overall number of tornado reports have increased since 1970. This may be a result of the implementation of improved warning verification by the NWS. An intriguing finding of this study is that the increase in reported tornado activity has been focused at the F0/F1 intensity scales, while there has been no significant increase in F2 or higher tornadoes. The northern Michigan tornado season is from March through October with the most active period occurring during June and July. No tornadoes have been reported during the winter months from November through February. The most active time of the day for tornadoes is late afternoon and early evening. In terms of spatial variability, the southeastern portion of the APX CWA tends to be the most active. This distribution can likely be attributed to the (stable) marine environment near Lake Michigan suppressing tornadic development over northwest lower Michigan, while enhanced easterly flow associated with lake breezes off of Lake Huron tends to enhance storm inflow, convergence, and helicity values over eastern parts of the APX CWA.

The goal of this study is to provide meteorologists and emergency managers with an understanding of when and where northern Michigan tornadoes occur. Future research may include a comprehensive study of all severe weather events across the APX CWA.

Satellite and Lightning Climatology for the Great Lakes

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GOES satellite data and lightning data are being combined to evaluate cloud and lightning patterns in the Great Lakes Region. 4 years (1998, 2000-2002) of GOES-8 data are being used to contruct 1- and 3-hourly time-composites of visible, water vapor and infrared images. The time-composites will be simple averages of the available images as well as being thresholded at certain critical values (50% albedo in the visible and -40C in the infrared). Lightning data
(positive, negative and in-cloud will be overlaid on the images). The combined images should be useful for identifying areas of thunderstorm initiation.

The primary focus will be on lightning, but differences between channel 4 and channel 2 (fog product) will be used to constuct a satellite fog climatology at the same time. Composite images will be created by compositing images where certain threshold are surpassed in difference between channel 4 and 2.